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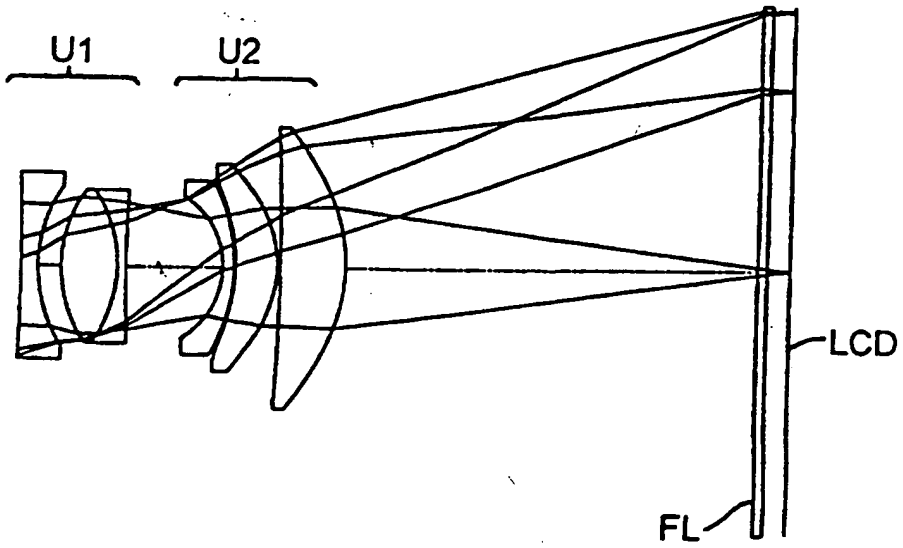
(54) Title: LCD PROJECTION LENS

(57) Abstract

A projection lens for use with a pixelized panel (LCD) is provided. The lens has two positive lens units (U1, U2) with an aperture stop between them. The optical powers of each of the units are such that f1 is substantially shorter than f2, where f1 and f2 are the focal lengths of the first lens unit (U1) and the second lens unit (U2), respectively, the first lens unit (U1) being on the system's long conjugate side and the second lens unit (U2) being on the short conjugate side. The ratio of f1 to f2 is preferably less than about 0.75.



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LCD PROJECTION LENS

FIELD OF THE INVENTION

This invention relates to projection lenses and, in particular, to projection lenses which can be used, inter alia, to form an image of an object composed of pixels, such as, a liquid crystal display (LCD).

BACKGROUND OF THE INVENTION

Projection lens systems (also referred to herein as "projection systems") are used to form an image of an object on a viewing screen. The basic structure of such a system is shown in Figure 7, wherein 10 is a light source (e.g., a tungsten-halogen lamp), 12 is illumination optics which forms an image of the light source (hereinafter referred to as the "output" of the illumination system), 14 is the object which is to be projected (e.g., a matrix of on and off pixels of a LCD panel), and 13 is a projection lens, composed of multiple lens elements, which forms an enlarged image of object 14 on viewing screen 16.

Projection lens systems in which the object is a LCD or other pixelized panel are used in a variety of applications, including data display systems. Such projection lens systems preferably employ a single projection lens which forms an image of either a single panel having, for example, red, green, and blue pixels, or three individual panels, one for each color. For ease of reference, the following discussion will be in terms of a projection lens system that employs a single LCD panel, it being understood that the invention can also be used in systems which employ multiple panels and/or other types of pixelization.

SUMMARY OF THE INVENTION

The projection lenses of the invention comprise two positive lens units with an aperture stop between them. The optical powers of each of

the units are such that f1 is substantially shorter than f2, where f1 and f2 are the focal lengths of the first lens unit and the second lens unit, respectively, the first lens unit being on the system's long conjugate side and the second lens unit being on the short conjugate side. In particular, the ratio of f1 to f2 is less than about 0.75. (See Table 7 and note that when the second unit includes a field lens, e.g., a Fresnel field lens, the value of f2 is calculated without the field lens.) In contrast, for a classical double gauss form, f1 is about the same as f2, or longer than f2.

The projection lenses of the invention are capable of covering a wide field of view. They have a back focal length approximately equal to the focal length of the lens. Each of the first and second lens units has at least one aspherical surface.

The first lens unit on the long conjugate side of the stop may consist of a single positive element. However, to obtain a better correction of residual astigmatism and chromatic aberrations, this unit may include a leading negative element closely followed by a positive component which may be a color correcting doublet. As illustrated in Tables 1-5, the spacing between the leading negative element and the positive component is at most about 5% of the focal length of the first lens unit.

The second lens unit behind the aperture stop includes a color correcting doublet and a single positive element with at least one aspherical surface. Most of the correction of spherical aberration is obtained in the first lens unit, while off-axis aberrations including coma and distortion, as well as chromatic aberrations, are corrected predominantly in the second lens unit.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1-6 are schematic side views of projection lenses constructed in accordance with the invention.

Figure 7 is a schematic diagram showing an overall projection lens system in which the projection lens of the present invention can be used.

The foregoing drawings, which are incorporated in and constitute part of the specification, illustrate the preferred embodiments of the invention, and together with the description, serve to explain the principles of the invention. It is to be understood, of course, that both the drawings and the description are explanatory only and are not restrictive of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figures 1 to 6 illustrate various projection lenses constructed in accordance with the invention. Corresponding prescriptions and optical properties appear in Tables 1 to 6, respectively. The correspondence between the lens units discussed above and the various elements and surfaces of the lenses of Tables 1-6 is set forth in Table 7.

HOYA or SCHOTT designations are used for the glasses employed in the lens systems. Equivalent glasses made by other manufacturers can be used in the practice of the invention. Industry acceptable materials are used for the styrene and acrylic elements.

The aspheric coefficients set forth in the tables are for use in the following equation:

$$z = \frac{cy^2}{1+[1-(1+k)c^2y^2]^{1/2}} + Dy^4 + Ey^6 + Fy^8 + Gy^{10} + Hy^{12} + Iy^{14}$$

where z is the surface sag at a distance y from the optical axis of the system, c is the curvature of the lens at the optical axis, and k is a conic constant.

The designation "a" associated with various surfaces in the tables represents an aspheric surface, i.e., a surface for which at least one of D, E, F, G, H, or I in the above equation is not zero. The designation "c" represents a conic surface for which the k value in the above equation is not zero. The designation "f" represents a Fresnel lens surface (the Fresnel lens is identified by the designation "FL" in Figures 1 and 3). All dimensions given in the tables are in millimeters. The tables are constructed on the assumption that light travels from left to right in the figures. In actual

practice, the viewing screen will be on the left and the LCD panel will be on the right, and light will travel from right to left.

Although specific embodiments of the invention have been described and illustrated, it is to be understood that a variety of modifications which do not depart from the scope and spirit of the invention will be evident to persons of ordinary skill in the art from the foregoing disclosure.

TABLE 1

Lens Data

Surf. No.	Type	Radius	Thickness	Glass	Clear Aperture Diameter
1	a	-1770.1750	8.00000	ACRYLIC	84.11
2	a	72.5195	10.00000		71.77
3		63.3660	25.00000	SK18	68.98
4		-63.3660	4.00000	KF6	65.89
5		762.9749	9.16228		60.48
6		Aperture stop	35.18800		57.72
7		-38.4192	5.00000	SF14	63.38
8		-81.9407	1.00000		80.13
9	a	-77.4031	18.00000	ACRYLIC	83.60
10	a	-57.0000	Space 1		93.65
11	c	-927.4539	29.50000	ACRYLIC	119.77
12	a	-79.0000	Space 2		124.99
13	cf	185.6000	4.00000	ACRYLIC	237.06
14		∞	Image distance		236.86

Symbol Description

a - Polynomial asphere
c - Conic section
f - Fresnel

Conics

Surface Number	Constant
11	-7.1739E+01
13	-1.7000E+00

Even Polynomial Aspheres

Surf. No.	D	E	F	G	H	I
1	-7.0051E-08	-6.3254E-12	-2.9530E-14	7.5364E-19	9.4792E-21	-3.0013E-24
2	7.7762E-08	1.2679E-11	1.0260E-13	-3.2966E-17	-1.6803E-21	1.6991E-23
9	4.1171E-07	2.1244E-10	1.0122E-14	4.0619E-18	4.4932E-21	-1.0666E-24
10	2.4362E-07	1.2454E-10	1.2955E-14	1.0067E-17	1.8340E-21	3.0151E-24
12	1.3759E-07	5.0414E-11	-2.7910E-15	1.1423E-18	3.9343E-23	-3.3950E-27

Variable Spaces

Zoom Pos.	Space 1 T(10)	Space 2 T(12)	Focal Shift	Image Distance
1	1.500	182.411	-1.425	10.021
2	0.500	190.200	-1.000	10.015
3	2.000	175.350	-1.800	10.013

TABLE 1 (continued)

First-Order Data

	Zoom Position 1	2	3
f/number	3.50	3.50	3.50
Magnification	-0.0645	-0.1000	-0.0322
Object Height	-1830.8	-1180.0	-3660.0
Object Distance	-3048.7	-1998.8	-6010.2
Effective Focal Length	198.28	202.52	194.61
Image Distance	10.021	10.015	10.013
Overall Length	3391.4	2348.3	6346.5
Forward Vertex Distance	342.78	349.56	336.21
Barrel Length	332.76	339.55	326.20
Stop Surface Number	6	6	6
Distance to Stop	0.00	0.00	0.00
Stop Diameter	55.244	56.621	54.042
Entrance Pupil Distance	40.838	40.838	40.838
Exit Pupil Distance	-2564.2	-2859.8	-2270.8

First Order Properties of Elements

Element Number	Surface Numbers	Power	f'	lpp	l'pp
1	1 2	-0.70980E-02	-140.88	5.1374	-0.21047
2	3 4	0.18681E-01	53.532	8.2520	-8.2520
3	4 5	-0.88988E-02	-112.38	0.20149	-2.4261
4	7 8	-0.10095E-01	-99.059	-2.6268	-5.6025
5	9 10	0.29494E-02	339.06	35.393	26.063
6	11 12	0.57837E-02	172.90	21.342	1.8179
7	13 14	0.26604E-02	375.88	-0.51716E-08	-2.6778

First-Order Properties of Doublets

Element Numbers	Surface Numbers	Power	f'	lpp	l'pp
2 3	3 5	0.11187E-01	89.389	1.5277	-16.542

First Order Properties of Groups

Group Number	Surface Numbers	Power	f'	lpp	l'pp
1	1 10	-0.26248E-03	-3809.7	495.35	349.41
2	11 12	0.57837E-02	172.90	21.342	1.8179
3	13 14	0.26604E-02	375.88	-0.51716E-08	-2.6778

First Order Properties of the Lens

Zoom Position Number	Power	f'	lpp	l'pp
1	0.50433E-02	198.28	223.78	-199.63
2	0.49377E-02	202.52	228.97	-211.76
3	0.51385E-02	194.61	218.81	-189.07

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TABLE 2

Lens Data

Surf. No.	Type	Radius	Thickness	Glass	Clear Aperture Diameter
1	a	-3501.6551	8.00000	ACRYLIC	83.97
2	a	73.8047	10.00000		72.07
3		63.9262	25.00000	SK18	69.86
4		-63.9262	4.00000	KF6	67.04
5		570.3825	2.53228		60.39
6		∞	41.97092		59.72
7		-39.0852	5.00000	SF14	64.45
8		-83.4350	1.00000		80.90
9	a	-77.4031	18.00000	ACRYLIC	83.88
10	a	-57.0000	0.50000		94.26
11	c	-927.4539	30.50000	ACRYLIC	119.04
12	a	-79.0000	194.22819		124.60

Symbol Description

a - Polynomial asphere
c - Conic section

Focal Shift = -1.97869

Conics

Surface Number	Constant
11	-7.5322E+01

Even Polynomial Aspheres

Surf. No.	D	E	F	G	H	I
1	-8.1680E-08	-9.0415E-12	-2.8846E-14	9.7292E-19	9.4877E-21	-2.8507E-24
2	6.1549E-08	5.4266E-12	9.8518E-14	-3.4835E-17	-1.5392E-21	1.7744E-23
9	3.8615E-07	1.8759E-10	1.0984E-14	7.6281E-18	5.6048E-21	-1.6720E-24
10	2.7112E-07	1.4686E-10	1.7530E-14	1.0200E-17	1.4695E-21	2.8348E-24
12	1.1260E-07	4.4374E-11	-2.9777E-15	1.1981E-18	4.3134E-23	-6.5187E-27

First Order Data

f/number	3.50	Overall Length	3505.33
Magnification	-0.0645	Forward Vertex Distance	340.731
Object Height	-1830.8	Barrel Length	146.503
Object Distance	-3164.60	Entrance Pupil Distance	40.9073
Effective Focal Length	198.998	Exit Pupil Distance	-145.903
Image Distance	194.228	Stop Diameter	57.224
Stop Surface Number	6	Distance to Stop	6.43

TABLE 2 (continued)

First Order Properties of Elements

Element Number	Surface Numbers	Power	f'	lpp	l'pp
1	1 2	-0.68364E-02	-146.28	5.2411	-0.11047
2	3 4	0.18530E-01	53.965	8.2460	-8.2460
3	4 5	-0.90617E-02	-110.35	0.26468	-2.3616
4	7 8	-0.99405E-02	-100.60	-2.6199	-5.5926
5	9 10	0.29494E-02	339.06	35.393	26.063
6	11 12	0.57859E-02	172.83	22.057	1.8788

First-Order Properties of Doublets

Element Numbers	Surface Numbers	Power	f'	lpp	l'pp
2 3	3 5	0.10898E-01	91.762	1.1692	-16.833

First Order Properties of the Lens

Power	f'	lpp	l'pp
0.50252E-02	199.00	119.64	-15.627

FIRST ORDER DATA, SURF 1 TO 5

K	PP1	PP2	f'
0.490176E-02	30.3186	-1.10148	204.00

FIRST ORDER DATA, SURF 7 TO 12

K	PP1	PP2	f'
0.232360E-02	147.569	172.803	430.37

TABLE 3

Lens Data

Surf. No.	Type	Radius	Thickness	Glass	Clear Aperture Diameter
1	a	-148.4666	6.00000	ACRYLIC	51.92
2	a	54.4747	0.50000		45.04
3		40.0292	15.00000	SK18	45.07
4		-130.3723	6.26676		42.15
5		Aperture stop	21.40605		34.58
6		-23.1527	3.00000	SF13	39.96
7		-64.2034	1.50000		54.39
8		-54.0449	16.67610	ACRYLIC	54.69
9	a	-35.8273	0.50000		63.68
10	a	-3465.3279	24.66862	ACRYLIC	93.09
11	a	-54.7193	121.94030		95.74
12	cf	120.0000	4.00000	ACRYLIC	166.79
13		∞	9.99997		166.48

Symbol Description

a - Polynomial asphere
c - Conic section
f - Fresnel

Focal Shift = -1.94463

Conics

Surface Number	Constant
12	-2.0085E+00

Even Polynomial Aspheres

Surf. No.	D	E	F	G	H	I
1	-1.0532E-06	-1.0364E-09	1.3079E-12	-2.2637E-15	4.0754E-18	-2.4681E-21
2	-1.0077E-06	1.3853E-10	-5.4208E-12	1.3555E-14	-3.2354E-18	-5.1055E-21
9	-7.2513E-07	1.8571E-09	-2.8477E-12	1.3532E-15	6.7032E-19	-5.6155E-22
10	-2.1332E-07	2.4887E-11	3.2458E-14	8.2905E-18	2.9285E-22	-1.2661E-25
11	5.7413E-07	4.5720E-11	4.8259E-14	2.5315E-17	-1.5472E-20	9.1310E-24

First Order Data

f/number	3.50	Overall Length	1401.46
Magnification	-0.1083	Forward Vertex Distance	231.458
Object Height	-762.00	Barrel Length	221.458
Object Distance	-1170.00	Entrance Pupil Distance	20.3913
Effective Focal Length	129.271	Exit Pupil Distance	5729.90
Image Distance	9.99997	Stop Diameter	34.576
Stop Surface Number	5	Distance to Stop	0.00

TABLE 3 (continued)

First Order Properties of Elements

Element Number	Surface Numbers	Power	f'	lpp	l'pp
1	1 2	-0.12511E-01	-79.928	2.9100	-1.0677
2	3 4	0.20219E-01	49.458	2.2234	-7.2414
3	6 7	-0.19987E-01	-50.032	-0.99970	-2.7722
4	8 9	0.60514E-02	165.25	25.425	16.855
5	10 11	0.89025E-02	112.33	16.739	0.26432
6	12 13	0.41148E-02	243.03	-0.82019E-08	-2.6778

First Order Properties of the Lens

Power	f'	lpp	l'pp
0.77357E-02	129.27	152.58	-131.33

TABLE 4

Lens Data

Surf. No.	Type	Radius	Thickness	Glass	Clear Aperture Diameter
1	a	-143.9480	6.00000	ACRYLIC	52.57
2	a	54.0933	0.50000		46.45
3		39.9766	15.00000	SK18	47.01
4		-138.3967	6.26676		44.55
5		-	23.26477		37.09
6		-23.3945	3.00000	SF13	41.34
7		-37.7517	1.50000		55.58
8		-50.6040	16.57162	ACRYLIC	56.00
9	a	-36.2946	0.50000		64.89
10	a	-2367.8999	24.39444	ACRYLIC	92.92
11	a	-54.6713	134.17166		95.59

Symbol Description

a - Polynomial asphere

Focal Shift - -1.24114

Even Polynomial Aspheres

Surf. No.	D	E	F	G	H	I
1	-7.8786E-07	-7.4301E-1[illegible]	1.2284E-12	-2.6558E-15	3.7917E-18	-1.8308E-21
2	-4.9688E-07	6.2284E-10	-5.5378E-12	1.2528E-14	-4.7256E-18	-2.2320E-21
9	-6.7035E-07	1.6035E-09	-2.8384E-12	1.4275E-15	6.5802E-19	-6.1437E-22
10	-2.4379E-07	2.3325E-11	3.2535E-14	8.2976E-18	2.0542E-22	-2.1158E-25
11	6.0221E-07	5.9205E-11	4.6922E-14	2.3851E-17	-1.6076E-20	8.9490E-24

First Order Data

f/number	3.50	Overall Length	1473.17
Magnification	-0.1083	Forward Vertex Distance	231.169
Object Height	-762.00	Barrel Length	96.9976
Object Distance	-1242.00	Entrance Pupil Distance	20.8429
Effective Focal Length	129.736	Exit Pupil Distance	-136.607
Image Distance	134.172	Stop Diameter	36.897
Stop Surface Number	5	Distance to Stop	0.45

First Order Properties of Elements

Element Number	Surface Numbers	Power	f'	lpp	l'pp
1	1 2	-0.12684E-01	-78.838	2.8906	-1.0862
2	3 4	0.19996E-01	50.010	2.1178	-7.3318
3	6 7	-0.18289E-01	-54.677	-1.2146	-2.9983
4	8 9	0.53197E-02	187.98	28.371	20.349
5	10 11	0.88539E-02	112.94	16.659	0.38462

TABLE 4 (continued)

First Order Properties of the Lens

Power	f'	lpp	l'pp
0.77080E-02	129.74	85.332	-8.3775

FIRST ORDER DATA, SURF 1 TO 4

K	PP1	PP2	f'
0.825105E-02	11.8672	-1.63760	121.20

FIRST ORDER DATA, SURF 6 TO 11

K	PP1	PP2	f'
0.412919E-02	105.968	138.422	242.18

TABLE 5

Lens Data

Surf. No.	Type	Radius	Thickness	Glass	Clear Aperture Diameter
1	a	-215.0838	6.00000	ACRYLIC	50.10
2	a	51.3941	0.50000		44.84
3		39.5202	15.00000	SK18	45.08
4		-204.0199	6.26676		41.86
5		∞	24.70386		37.34
6		-23.5819	3.00000	SF13	42.80
7		-54.9838	17.48359	SK5	58.11
8		-38.5513	0.50000		68.16
9	a	-442.7462	22.96924	ACRYLIC	93.18
10	a	-54.6936	133.38308		95.54

Symbol Description

a - Polynomial asphere

Focal Shift = -1.06757

Even Polynomial Aspheres

Surf. No.	D	E	F	G	H	I
1	-6.2558E-07	-6.6007E-10	1.3377E-12	-2.7764E-15	3.6207E-18	-1.7047E-21
2	-4.7729E-07	2.8390E-10	-5.2520E-12	1.3608E-14	-6.5024E-18	-3.3618E-21
9	-4.6643E-08	3.6819E-11	2.8968E-14	8.8163E-18	1.7148E-21	2.3288E-25
10	5.3589E-07	1.0862E-10	4.8657E-14	2.7503E-17	-1.4201E-20	9.3743E-24

First Order Data

f/number	3.50	Overall Length	1471.80
Magnification	-0.1083	Forward Vertex Distance	229.807
Object Height	-762.00	Barrel Length	96.4234
Object Distance	-1241.99	Entrance Pupil Distance	19.6498
Effective Focal Length	129.598	Exit Pupil Distance	-136.742
Image Distance	133.383	Stop Diameter	37.137
Stop Surface Number	5	Distance to Stop	-0.86

First Order Properties of Elements

Element Number	Surface Numbers	Power	f'	lpp	l'pp
1	1 2	-0.11992E-01	-83.389	3.2180	-0.76895
2	3 4	0.18904E-01	52.899	1.5196	-7.8449
3	6 7	-0.17354E-01	-57.623	-1.3444	-3.1347
4	7 8	0.63978E-02	156.30	26.344	18.471
5	9 10	0.80676E-02	123.95	17.207	2.1256

TABLE 5 (continued)

First-Order Properties of Doublets

Element Numbers	Surface Numbers	Power	f'	lpp	l'pp
3 4	6 8	-0.76835E-02	-130.15	-25.890	-48.110

First Order Properties of the Lens

Power	f'	lpp	l'pp
0.77162E-02	129.60	83.934	-9.1868

FIRST ORDER DATA, SURF 1 TO 4

K	PP1	PP2
0.754400E-02	10.2057	-3.41220

FIRST ORDER DATA, SURF 6 TO 10

K	PP1	PP2
0.446394E-02	93.0606	115.413

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TABLE 6

Lens Data

Surf. No.	Type	Radius	Thickness	Glass	Clear Aperture Diameter
1	a	94.4760	15.00000	STYRENE	42.78
2	a	-528.9612	0.50000		37.32
3		∞	21.29889		36.84
4		-27.7690	3.00000	STYRENE	40.46
5	a	-407.8987	4.00000		53.21
6		-74.3345	12.15783	BK7	53.55
7		-42.4453	0.50000		61.02
8	a	164.4718	26.97190	ACRYLIC	92.86
9	a	-62.3055	135.01787		95.37

Symbol Description

a - Polynomial asphere

Focal Shift = 0.74200

Even Polynomial Aspheres

Surf. No.	D	E	F	G	H	I
1	-2.1948E-07	-3.1161E-09	7.4142E-12	-1.0377E-14	-2.2299E-17	3.2858E-20
2	-1.5111E-06	-5.1899E-09	-8.6485E-12	2.3336E-14	2.8430E-17	-1.0133E-19
5	-3.9131E-07	-6.8333E-10	5.5582E-13	6.5433E-16	1.3386E-20	-7.1347E-22
8	-2.9686E-07	-3.7064E-12	9.5859E-15	4.9355E-18	1.5459E-21	5.8285E-25
9	5.6173E-07	1.1183E-10	1.3209E-14	1.5832E-17	-1.7718E-20	7.9237E-24

First Order Data

f/number	3.50	Overall Length	1460.42
Magnification	-0.1083	Forward Vertex Distance	218.446
Object Height	-762.00	Barrel Length	83.4286
Object Distance	-1241.97	Entrance Pupil Distance	14.3855
Effective Focal Length	128.370	Exit Pupil Distance	-110.515
Image Distance	135.018	Stop Diameter	35.707
Stop Surface Number	3	Distance to Stop	3.27

First Order Properties of Elements

Element Number	Surface Numbers		Power	f'	lpp	l'pp
1	1	2	0.73555E-02	135.95	1.4381	-8.0518
2	4	5	-0.19908E-01	-50.232	-0.13781	-2.0243
3	6	7	0.59254E-02	168.76	16.511	9.4276
4	8	9	0.10498E-01	95.259	13.631	-5.1638

TABLE 6 (continued)

First Order Properties of the Lens

Power	f'	lpp	l'pp
0.77900E-02	128.37	71.383	-7.9999

FIRST ORDER DATA, SURF 4 TO 9

K	PP1	PP2
0.444232E-02	92.8040	107.813

TABLE 7

	Unit 1	Unit 2				
Ex. No.	Surf. Nos.	Surf. Nos.	f 1	f 2	f	f1/f2
1	1 to 5	7 to 12	199.16	448.33*	198.99*	0.444
2	1 to 5	7 to 12	204.00	430.37	199.00	0.474
3	1 to 4	6 to 11	115.38	257.84*	129.60*	0.447
4	1 to 4	6 to 11	121.20	242.18	129.74	0.500
5	1 to 4	6 to 10	132.56	224.02	129.60	0.592
6	1 to 2	4 to 9	135.95	225.11	128.37	0.604

*Value calculated without the Fresnel lens since the Fresnel lens is primarily a field lens which serves to couple the lens' entrance pupil to the exit pupil of the illumination system. As such, the Fresnel lens has a minimal effect on the overall focal length of the lens, but a large effect on the value of f2, which effect is not representative of the actual functioning of the f2 unit.

What is claimed is:

1. A projection lens for forming an image of an object, said lens having an aperture stop and comprising in order from its image end to its object end:

   (a) a first lens unit having a positive optical power and a focal length f1;

   (b) a second lens unit having a positive optical power and a focal length f2;

   wherein the aperture stop is located between the first and second lens units and f1 is substantially shorter than f2.

2. The projection lens of Claim 1 wherein the ratio of f1 to f2 is less than about 0.75.

3. The projection lens of Claim 1 wherein the lens has a back focal length approximately equal to the lens' focal length.

4. The projection lens of Claim 1 wherein each of the first and second lens units has at least one aspherical surface.

5. The projection lens of Claim 1 wherein the first lens unit consists of a single positive lens element.

6. The projection lens of Claim 1 wherein the first lens unit comprises in order from its image end:

   (a) a negative lens element; and

   (b) a positive lens subunit.

7. The projection lens of Claim 6 wherein the positive lens subunit is closely spaced to the negative lens element.

8. The projection lens of Claim 6 wherein the positive lens subunit is a color correcting doublet.

9. The projection lens of Claim 1 wherein the second lens unit comprises a color correcting doublet and a positive lens element which has at least one aspherical surface.

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10. The projection lens of Claim 6 wherein the second lens unit comprises a color correcting doublet and a positive lens element which has at least one aspherical surface.

11. The projection lens of Claim 7 wherein the second lens unit comprises a color correcting doublet and a positive lens element which has at least one aspherical surface.

12. The projection lens of Claim 8 wherein the second lens unit comprises a color correcting doublet and a positive lens element which has at least one aspherical surface.

13. A projection lens system for forming an image of an object, said system comprising:

(a) an illumination system comprising a light source and illumination optics which forms an image of the light source;

(b) a pixelized panel which comprises the object; and

(c) the projection lens of Claim 1.

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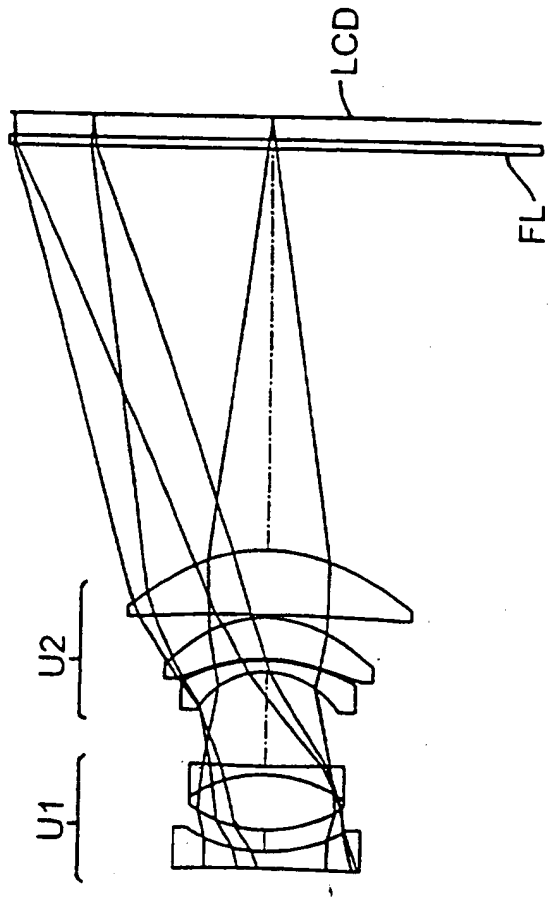

FIG. 1

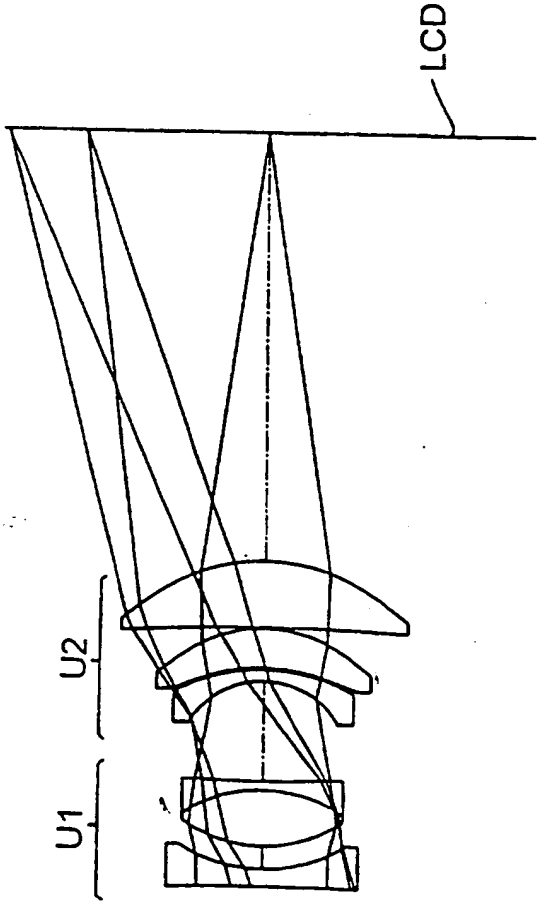

FIG. 2

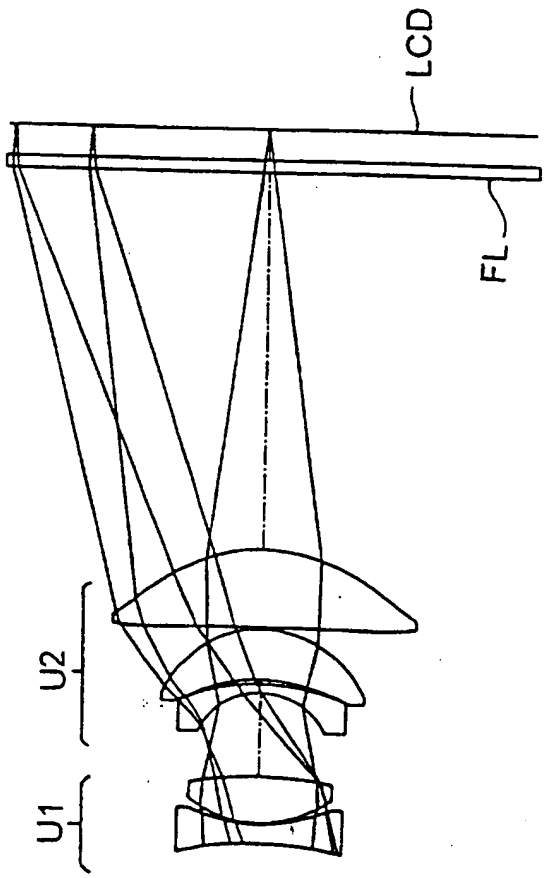

FIG. 3

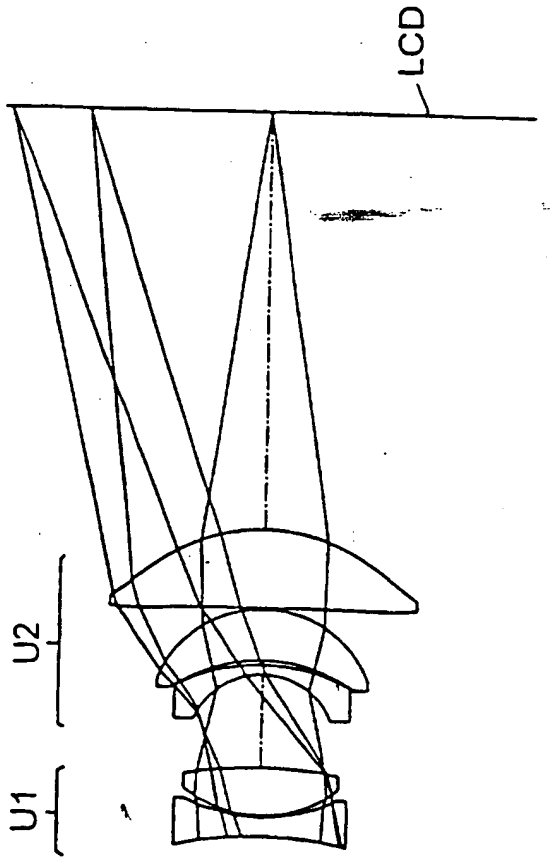

FIG. 4

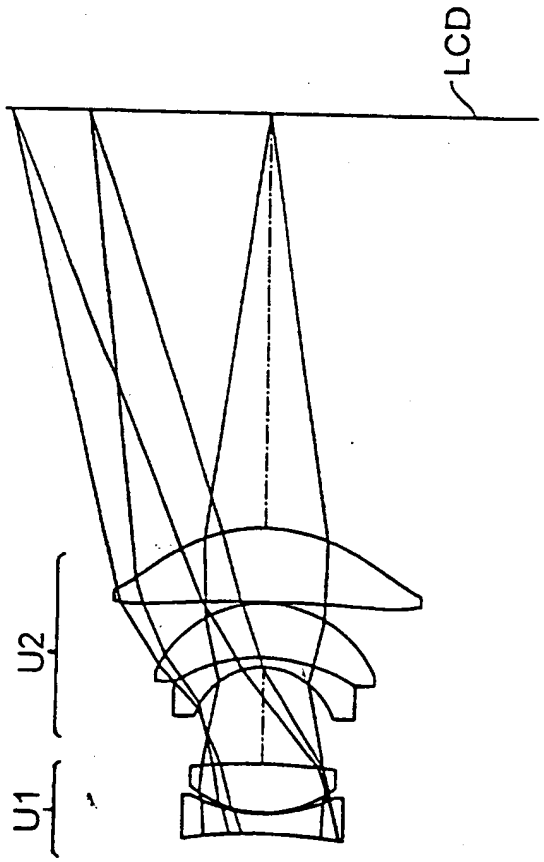

FIG. 5

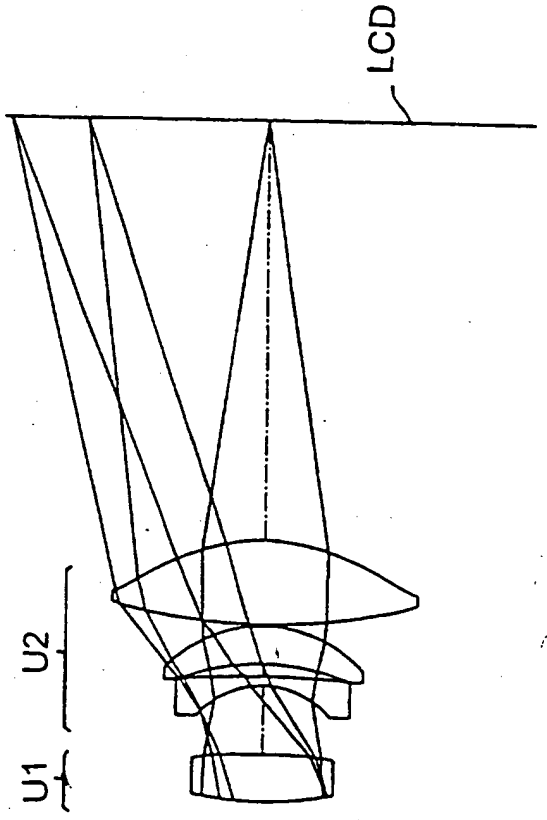

FIG. 6

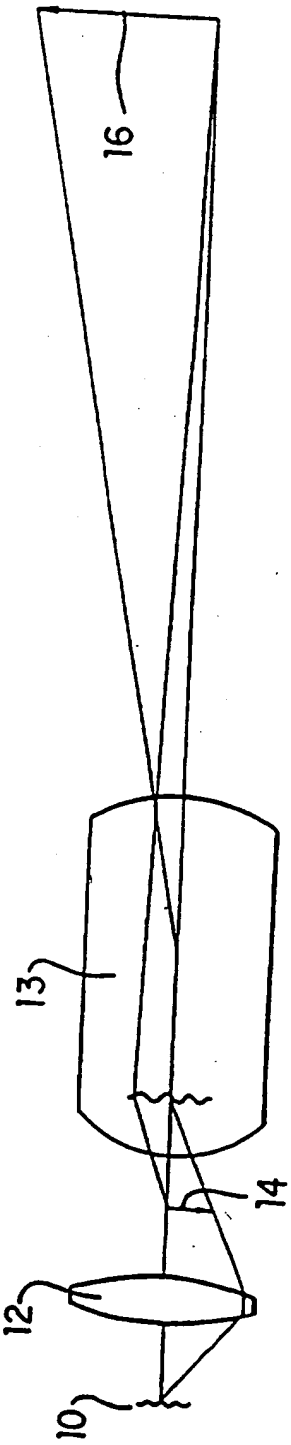

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/07686

A. CLASSIFICATION OF SUBJECT MATTER
IPC(6) :G02B 3/00, G02B 9/00, G02B 9/06
US CL :359/649, 650, 651, 717, 740, 794
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 359/649, 650, 651, 717, 740, 794

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
none

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
APS
search terms: projection lens/ti, aspheric, diaphragm, stop, aperture, color correct, doublet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,776,681 A (Moskovich) 11 October 1988 (11.10.88), see entire document, especially figure 2 and the accompanying text	1,2,4,5,13
A	US 5,066,113 A (Nakajima et al) 19 November 1991 (19.11.91)	1-13
X,P ---- Y	US 5,600,488 A (Minefuji et al) 04 February 1997 (04.02.97), see entire document, especially figures 1, 4, 16 22, 32 and their accompanying text, plus Embodiments 8 and 9.	1,2,4,5,9, 13 ---------- 6-8, 10-12

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
07 AUGUST 1997

Date of mailing of the international search report
21 AUG 1997

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